Evaluating Devonian Gas-Shales from the Appalachian Basin, U.S.A.*

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Abstract

Desorbed core gas quantities, kerogen and methane carbon isotopes, total organic carbon (TOC), pyrolysis parameters, and detailed mineralogy were determined for approximately 200 Devonian shale core samples in the Appalachian Basin from New York, Virginia, West Virginia, Kentucky, Pennsylvania, and Ohio. The data from core samples indicate varying levels of thermal maturity, total organic carbon (TOC) content, mineralogy, and gas content. TOC content for the shales ranges from < 0.1% to more than 10.0%, with gas content increasing with an increase in TOC. Thermal maturity and mineralogy also appear to influence gas content.

Methane carbon isotopes and thermal maturity data provide valuable information for evaluating the type of shale gas resource (indigenous versus migrated) in shale reservoirs. Methane carbon isotope values become less negative as thermal maturity increases. However, in some instances, methane carbon isotope values fall off of the maturity trend, suggesting the shales contain gases that are a mixture of indigenous and migrated gas. By integrating various geochemical techniques, insight into the processes resulting in accumulation of gas in shale reservoirs can be evaluated.

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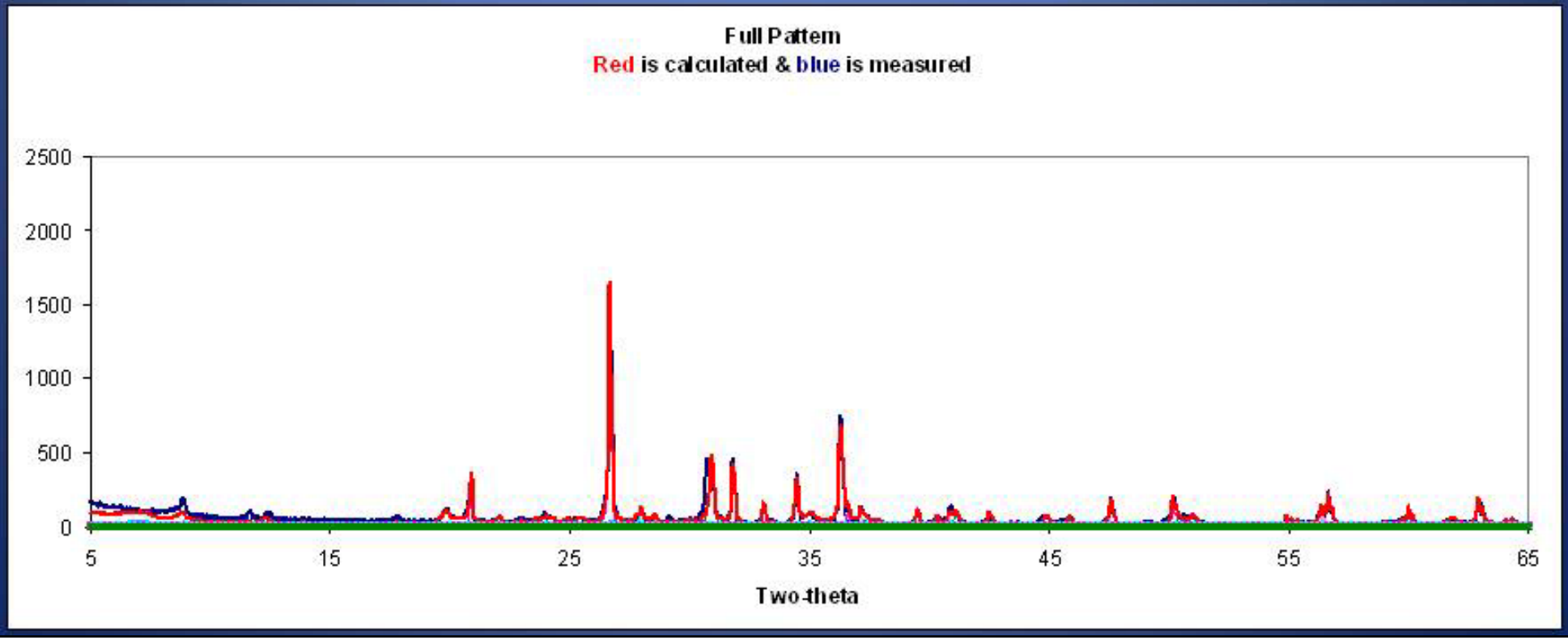
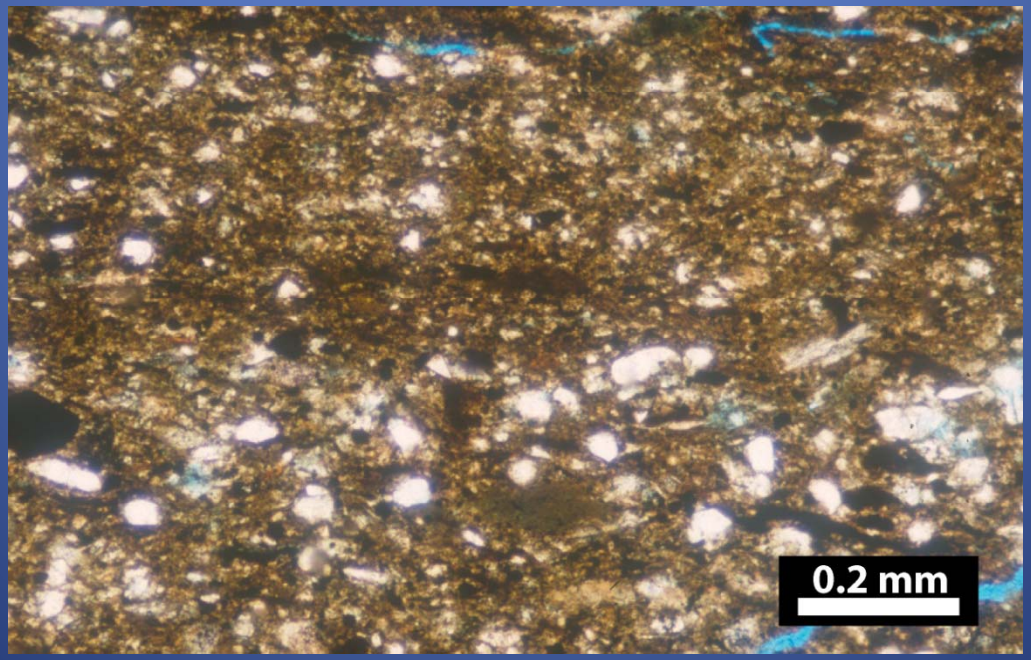
- X-ray prep
- x-ray analysis

Rock Jock, Eberl, 2003



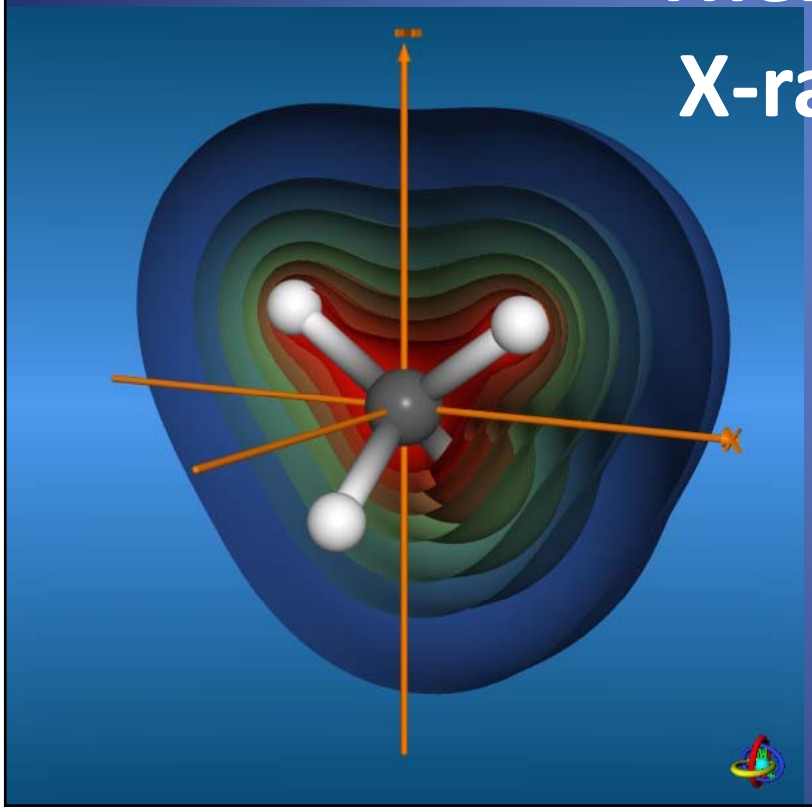
Outline

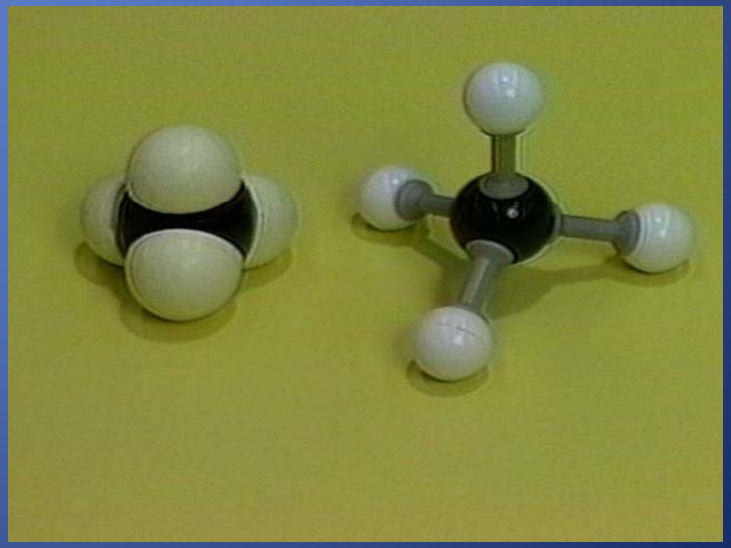
Methods
Sample location
TOC characteristics
Gas geochemistry
Shale mineralogy
Implications
Summary



Methods

Desorbed gas composition
Desorbed gas isotopes
Thermal maturity
X-ray diffraction





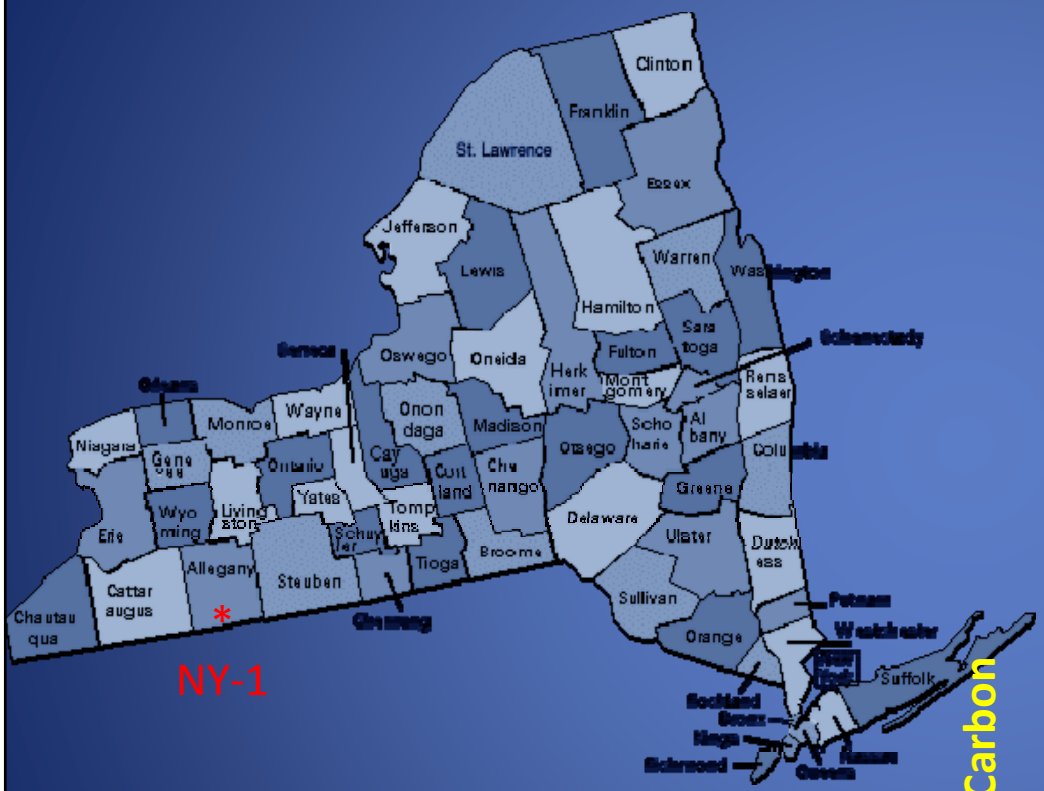
Appalachian Basin Gas Shale Sample Locations

171 Samples - Total Organic Carbon (TOC), Thermal Maturity (Tmax), Desorbed gas composition, Desorbed methane $\delta^{13}C$

New York (10)
NY-1 Allegany County
Ohio (49)
OH-3 Knox County
OH-4 Ashtabula County
OH-5 Lorain County
OH-7 Trumbull County
Pennsylvania (48)
PA-1 McKean County
PA-2 Allegheny County
PA-3 Erie County
PA-4 Indiana County
West Virginia (24)
WV-5 Mason County
WV-6 Monongalia County
WV-7 Wetzel County
Virginia (12)
VA-1 Wise County
Kentucky (28)
KY-3 Martin County
KY-4 Johnson County

New York Sample Locations And Total Organic Carbon (TOC)

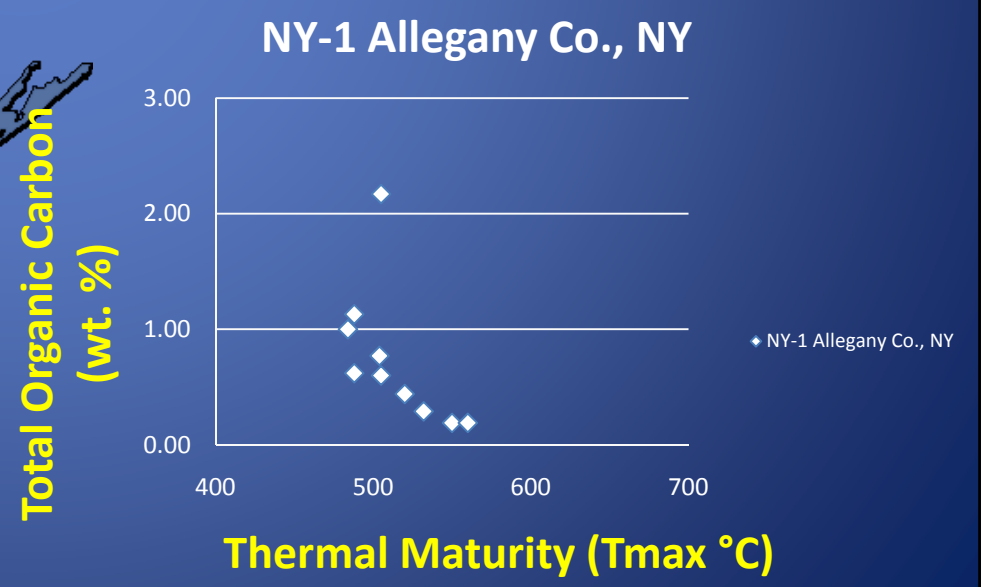
The Geneseo Shale shows the best TOC characteristics



New York (10)

NY-1 Allegany County

ROCK UNIT	TOC WT.%	Tmax (°C)
Angola	0.3 - 1.1	488-532
Rhinestreet	0.2 – 0.6	488-550
Cashaqua	0.2	560
Middlesex	0.8	504
Penn Yan	0.4 - 1.0	484-520
Geneseo	2.2	505



Ohio Sample Locations and Total Organic Carbon (TOC)

Huron, Lower Huron, Rhinestreet and Marcellus shales show best TOC characteristics

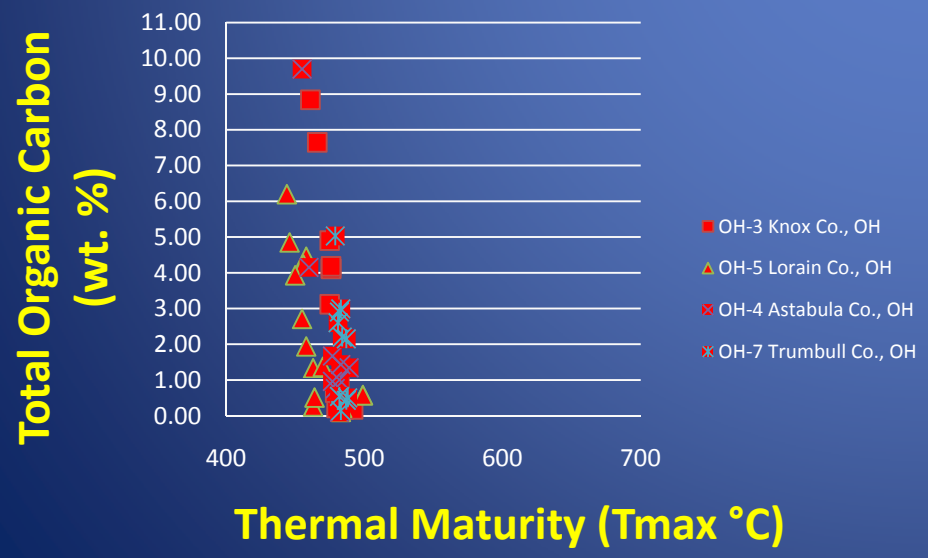
Ohio (49)

OH-3 Knox County

OH-4 Ashtabula County

OH-5 Lorain County

OH-7 Trumbull County



Rock Unit	TOC (Wt. %)	Carbon (°C)
Bedford	0.17	485
Chagrin	0.22	463-499
Huron	0.6 – 9.7	444-489
Lower Huron	3.8 - 8.8	461-475
Hanover	1.4	470-482
Rhinestreet	0.1-5.0	460-483
Skaneateles	0.6	483
Olentangy	0.40	483-484
Onandaga	0.18	492
Marcellus		3.0
483		

Pennsylvania Sample Locations and Total Organic Carbon (TOC)

Dunkirk, Genesee, Rhinestreet, Skaneateles, and Marcellus shales show best TOC characteristics

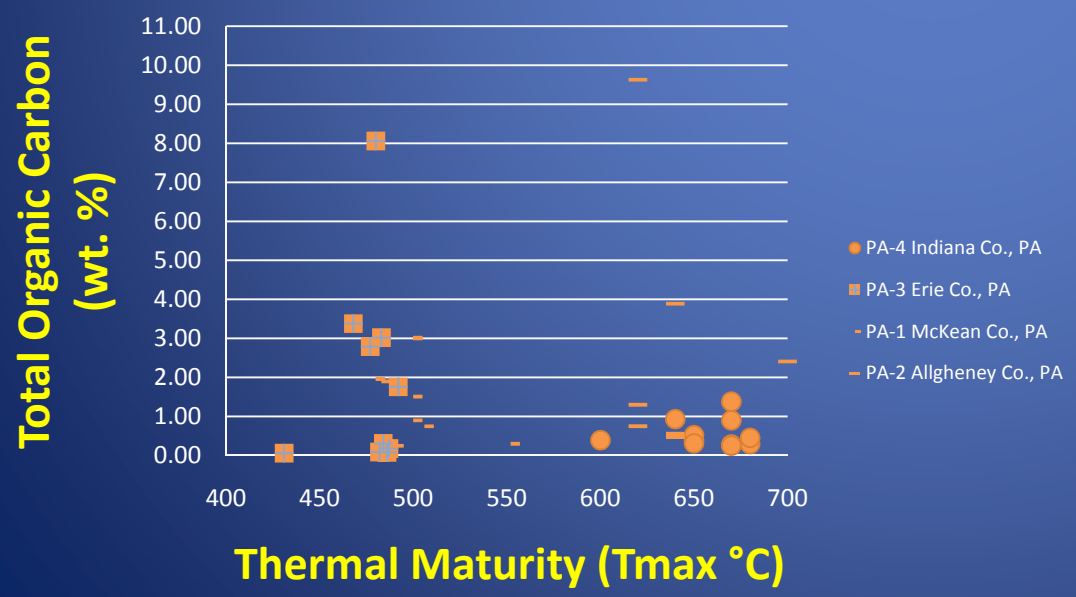
Pennsylvania (48)

PA-1 McKean County

PA-2 Allegheny County

PA-3 Erie County

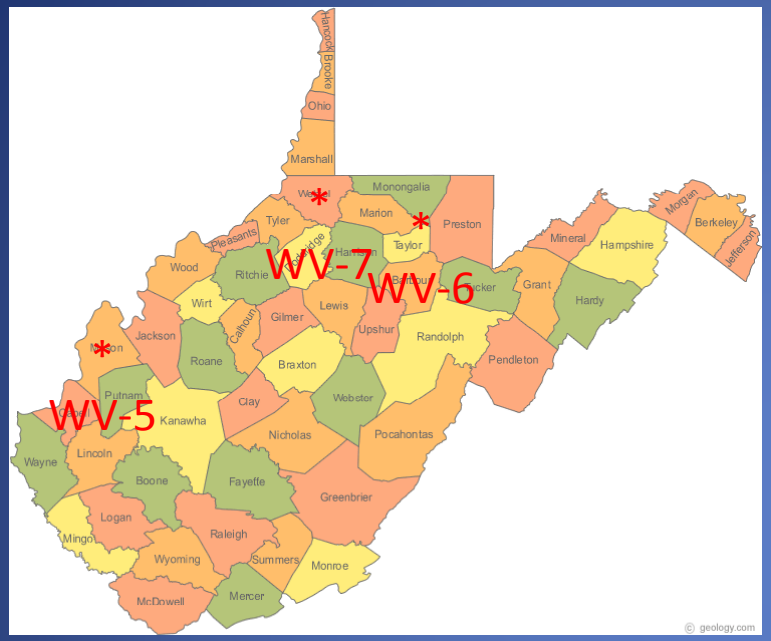
PA-4 Indiana County



Rock Unit	TOC (Wt. %)	Tmax (°C)
Perrysburg	0.1	482
Dunkirk	1.8 – 3.4	468-492
Hanover	0.1 – 0.3	431-490
Sonyea	0.3 – 1.9	483-680
Geneseo	0.4 – 6.9	500-680
Tully	0.15	-
Pipe Creek	0.1	486
Rhinestreet	2.8-3.0	477-483
Moscow/Ludlowville	0.2 – 1.3	506-650
Skaneateles	0.3 – 3.0	480-670
Marcellus	1.4 – 9.6	620-700

West Virginia Sample Locations and Total Organic Carbon (TOC)

West River, Skaneateles, Marcellus, and Lower Huron shales show best TOC characteristics

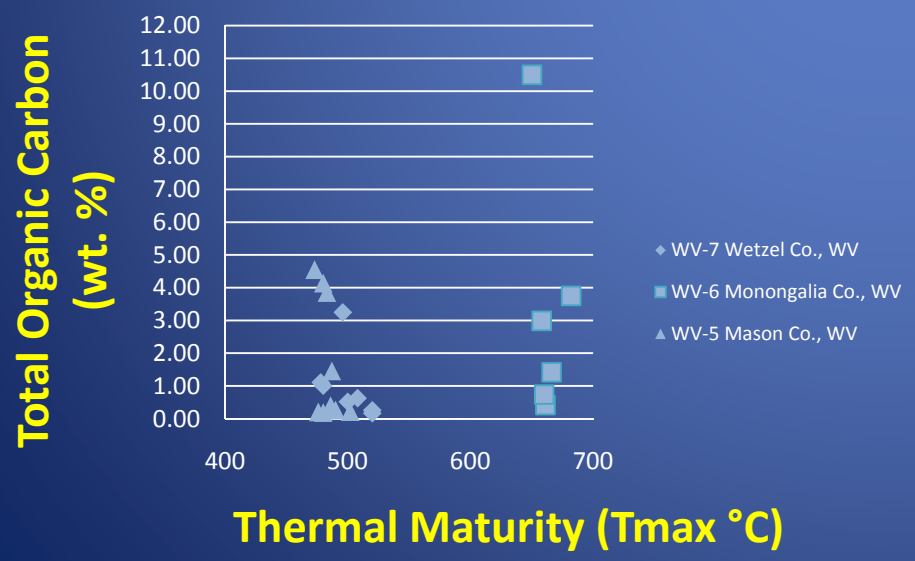


West Virginia (24)

WV-5 Mason County

WV-6 Monongalia County

WV-7 Wetzel County



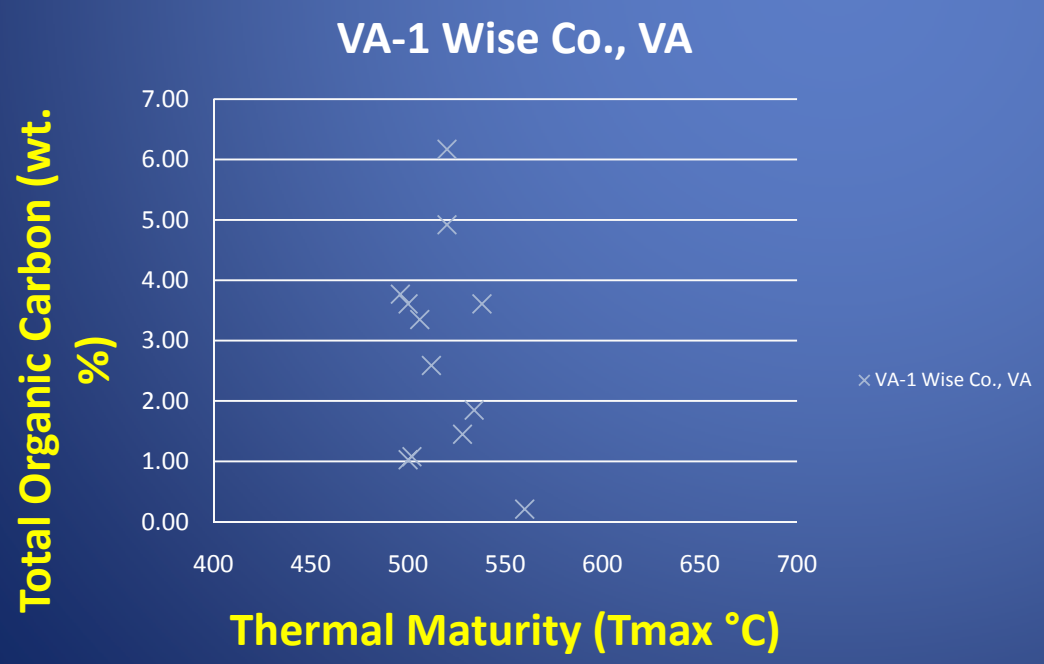
Rock Unit	TOC (Wt. %)	Tmax (°C)
Rhinestreet	0.2 – 1.1	478-520
Sonyea	0.3 – 0.6	508-520
West River	0.5 – 3.3	496-500
Moscow	0.4	661
Ludlowville	0.7 - 1.4	660-666
Skaneateles	3.0	658
Marcellus	3.8 - 10.5	650-682
Lower Huron	0.2 – 4.6	480-486
Hanover	0.2 - 1.5	487-502
Angola	0.2 – 0.3	476-490

Virginia Sample Locations and Total Organic Carbon (TOC)

Cleveland and Lower Huron shales show best TOC characteristics

Virginia (12)

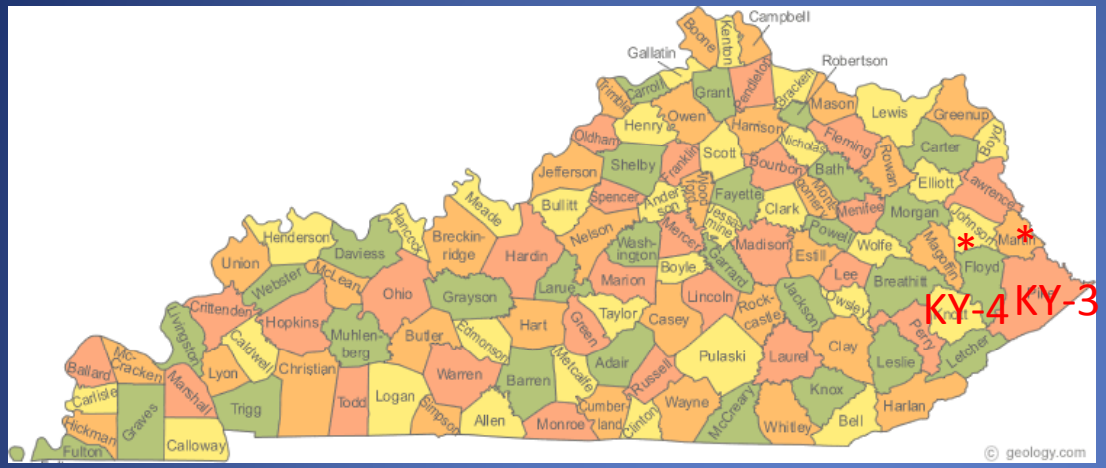
VA-1 Wise County



Rock Unit	TOC (Wt. %)	Tmax (°C)
Cleveland	3.3 - 6.2	500-520
Chagrin	0.2	560
Huron	1.1	500-502
L. Huron	1.5 – 4.9	496-538

Kentucky Sample Locations and Total Organic Carbon (TOC)

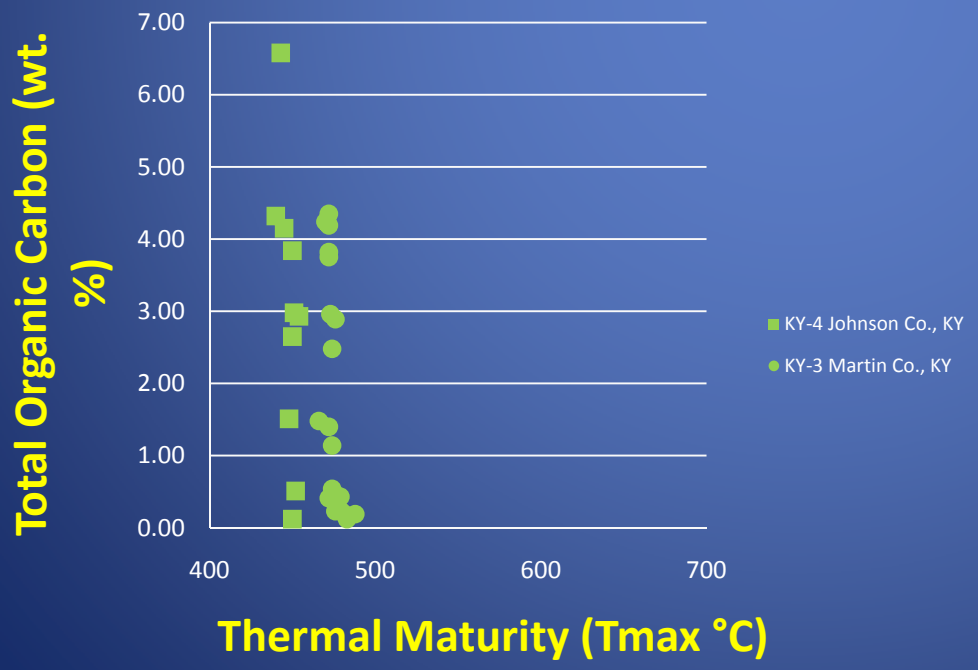
Cleveland, Chagrin, Huron, Lower Huron, Angola, and Rhinestreet shales show best TOC characteristics



Kentucky (28)

KY-3 Martin County

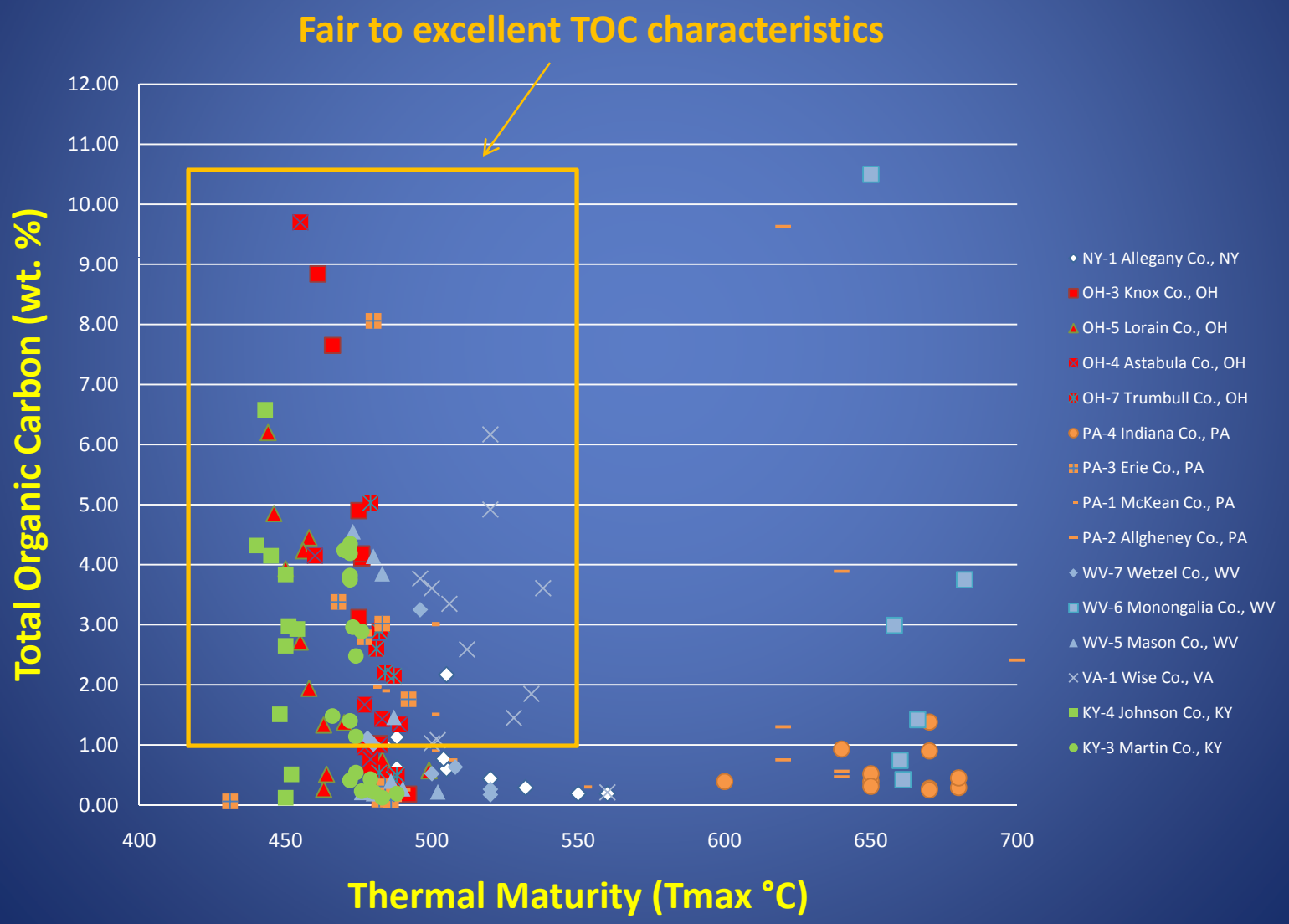
KY-4 Johnson County



Rock Unit	TOC (Wt. %)	Tmax (°C)
Bedford	0.51	452
Cleveland	0.43 - 2.9	451-479
Chagrin	0.2 – 2.5	474-480
Three Lick	2.9	454
Huron	1.1 – 4.2	445-476
L. Huron	3.8 – 6.6	440-472
Hanover	0.1 – 0.4	472-488
Angola	0.1 – 4.2	450-483
Rhinestreet	3.8	472

Thermal Maturity versus Total Organic Carbon

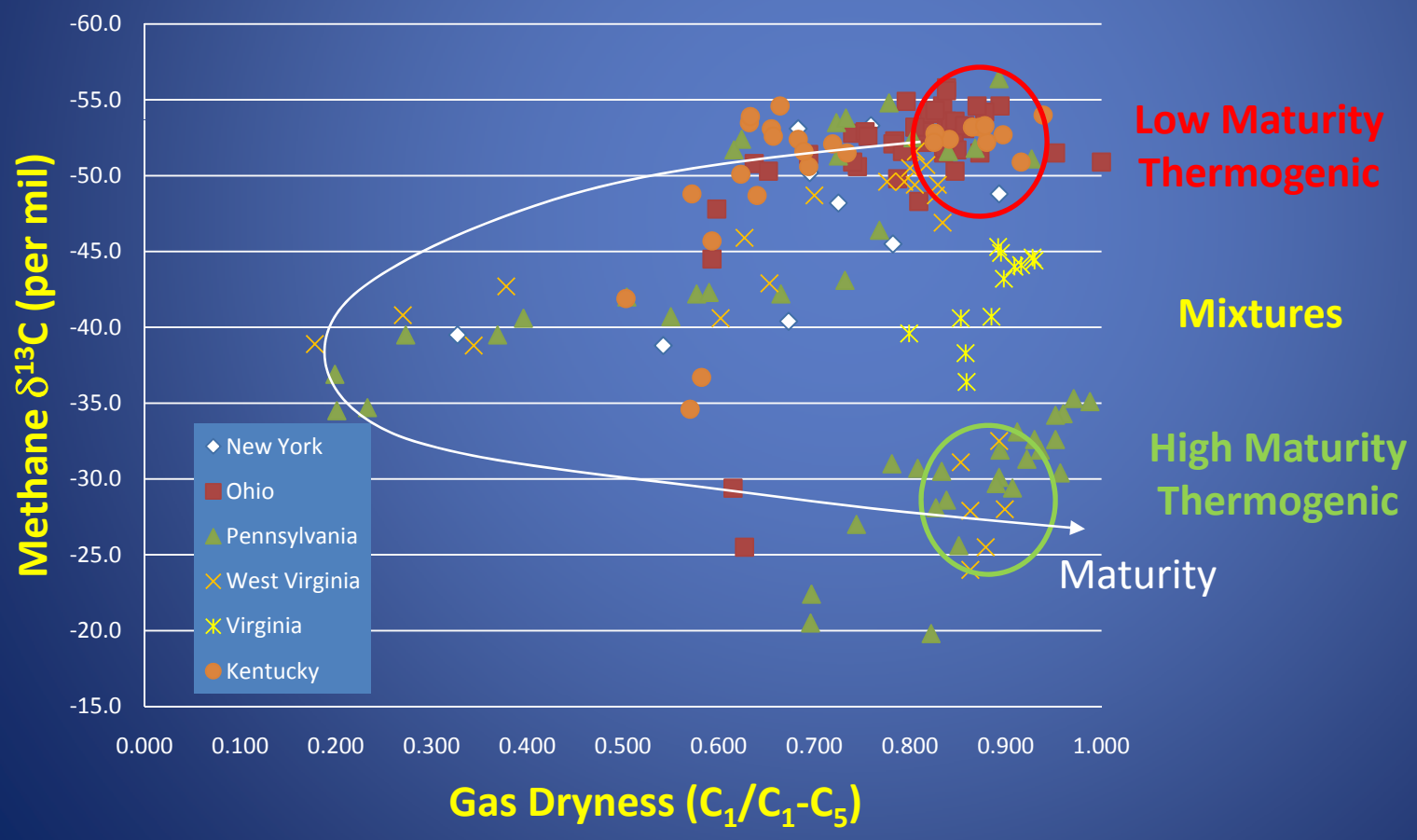
Appalachian Basin shales have considerable potential



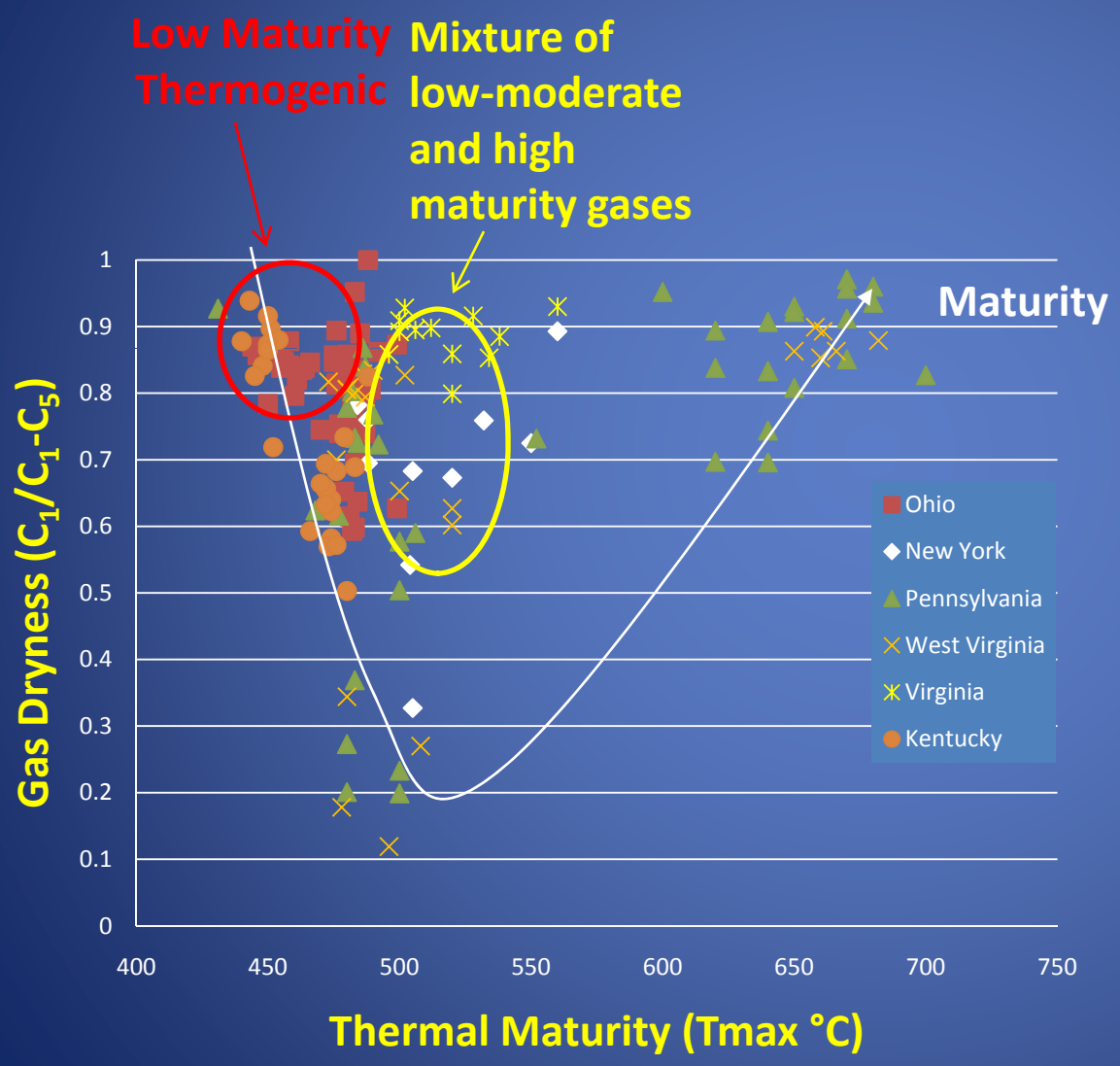
Geochemistry of gases from shales in study area

Gas geochemistry

- **Low maturity thermogenic source**
- **High maturity thermogenic source**
- **Mixtures**



Thermal Maturity versus Gas Composition



Low maturity thermogenic

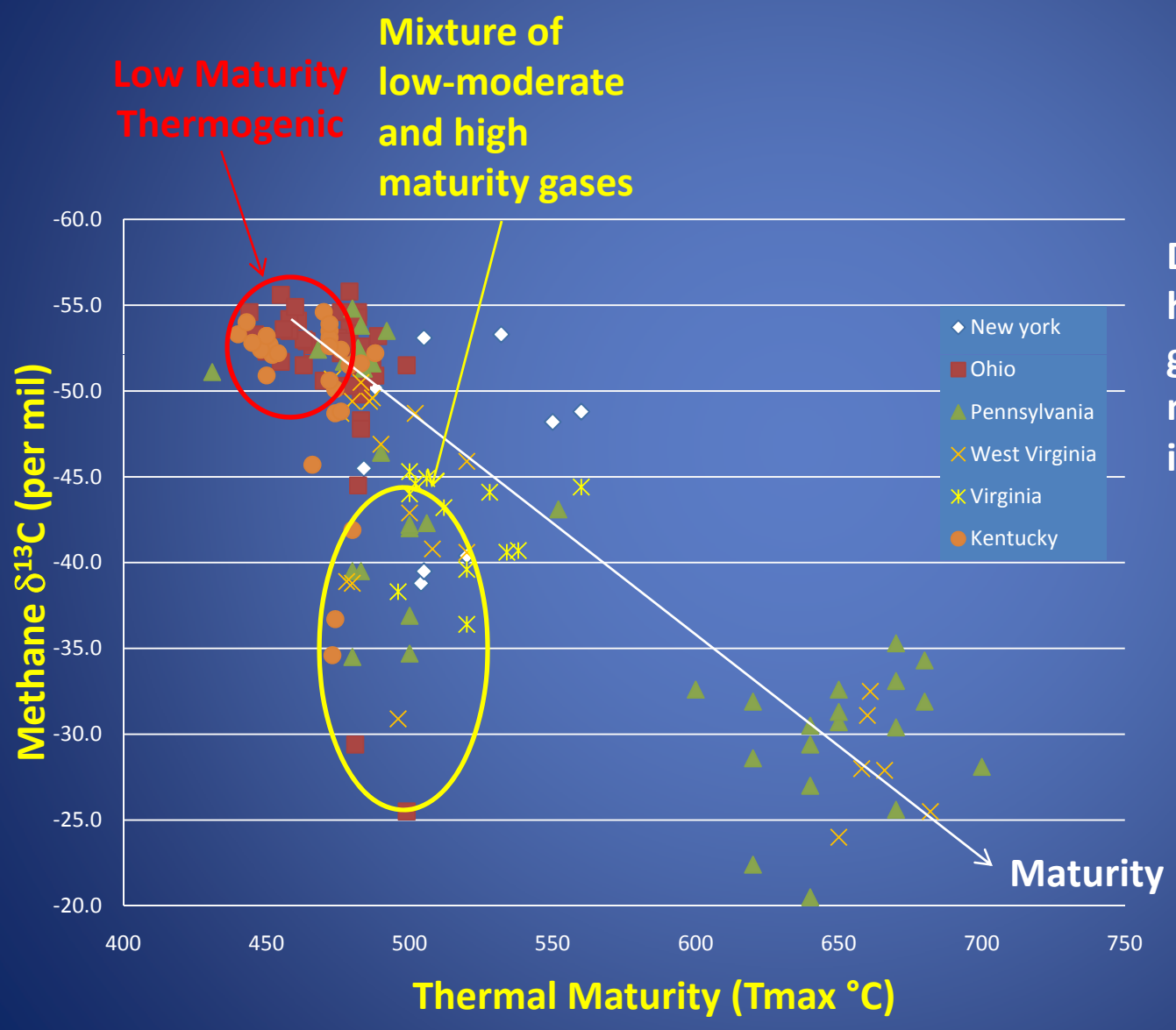
- Dry – high methane content
- C_{2+} hydrocarbons present

Mixtures

- High maturity methane
- Low-moderate maturity gas

Thermal Maturity versus Methane $\delta^{13}C$

Isotope data support mixing of low-moderate and high maturity gases



Data suggest deeper, high maturity, migrated gas is mixing with low-moderate maturity indigenous gases in shales

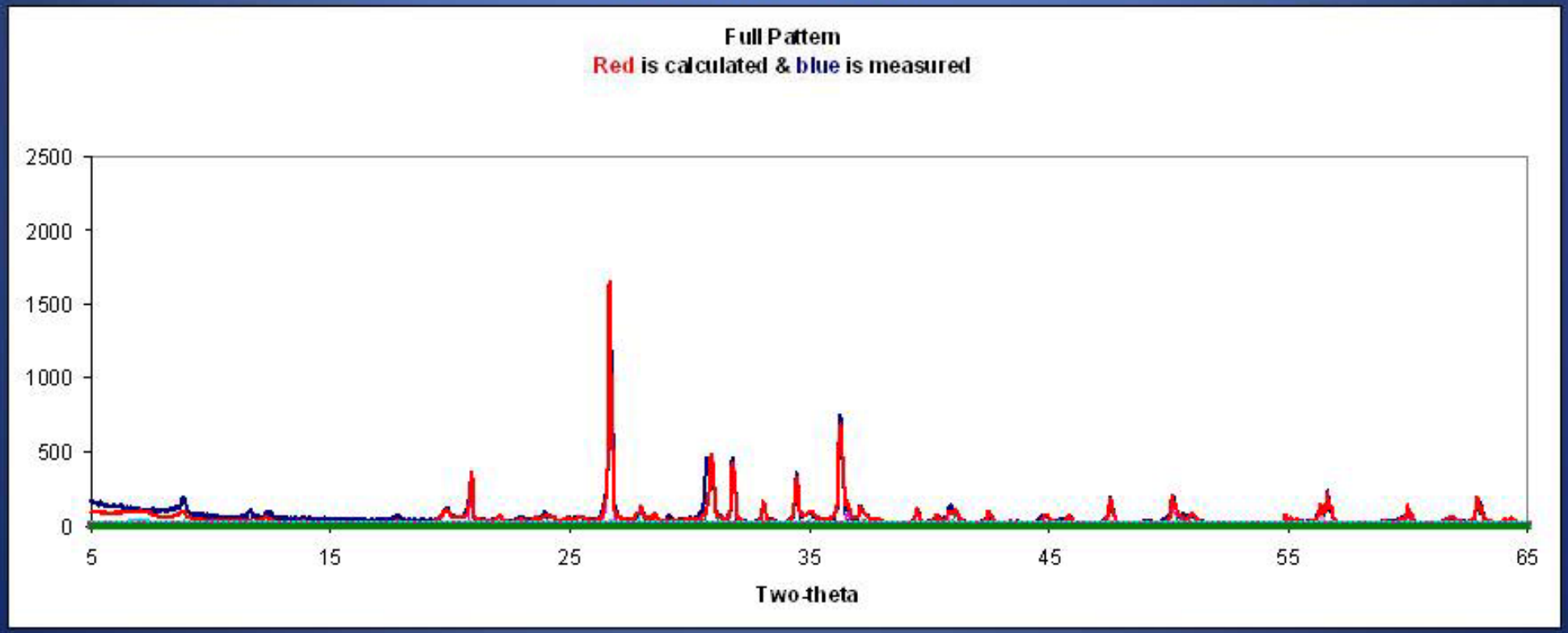
Shale Mineralogy

Rock Jock - Mineral Quantification

Mineral standards used to calculate a pattern that is fitted to the unknown pattern

Quantitative mineral amounts determined

Rock Jock, Eberl, 2003



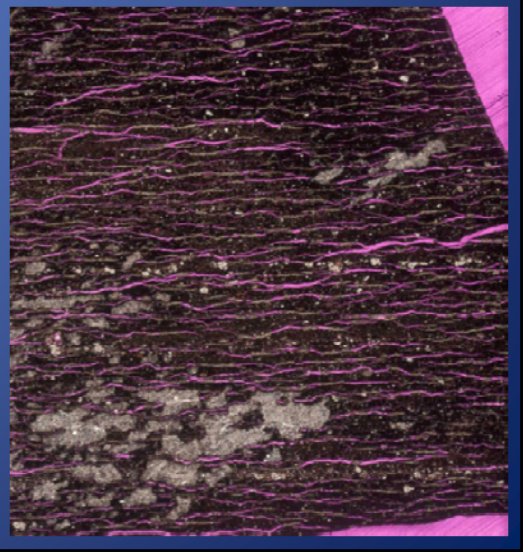
Quantitative Mineralogy

Mineral totals

- Clay totals 20-60%
- Non-clays 40-80% - quartz and carbonates are dominant

Quartz	31.2
intermediate Microcline feldspar	0.4
Albite feldspar (Cleavelandite)	7.1
Calcite	0.3
Fe-Dolomite	1.2
Ankerite	19.2
Pyroxene (diopside)	0.0
Pyrite	4.4
Hematite	0.4
Anatase	0.2
Total non-clays	64.3

CLAYS	
disordered Kaolinite	4.2
Ca-smectite (Wyo)	7.4
1M illite (RM30)	3.5
Glauconite	9.4
Fe-Chlorite (Tusc)	1.1
Muscovite (2M1)	10.2
Total clays	35.7
TOTAL	100.0



Fracturability is high for some shales

Good reservoir characteristics

Summary

Samples analyzed from New York (10), Ohio (49), Pennsylvania (48), West Virginia (24), Virginia (12), and Kentucky (28)

Total organic carbon characteristics range from poor (< 0.5%) to excellent (>10%)
Geneseo, Huron, Lower Huron, Rhinestreet, Skaneatelles, Marcellus show best potential

Gas Geochemistry
- Low maturity thermogenic gases
- High maturity thermogenic gases
- Mixtures

Shale Mineralogy
- 20-60% clays
- 40-80% quartz and carbonates
- Good reservoir potential

Reference

Eberl, D.D., 2003, RockJock (free program for calculating mineral weight percents from powder X-ray diffraction data): Web access 12 November 2008, (ftp://brrcrftp.cr.usgs.gov/pub/ddeberl)